THE DISTRIBUTION OF THE UPLAND PLANT SOCIETIES OF KENT COUNTY, MICHIGAN.[1]

CONTRIBUTIONS FROM THE HULL BOTANICAL LABORATORY. XLIII.

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(WITH MAP)

INTRODUCTION.

1. CLIMATOLOGY OF THE COUNTY.—Kent county is so situated that it is traversed both by the southern boundary of the pine-forest region and the eastern boundary of the so-called Michigan peach belt. It is also crossed by the Grand River valley, the line of one of the great main channels by which the melting ice of the glacial period reached the Mississippi system and the Gulf, and also the line marking the farthest northern extension within the peninsula of many typically southern plants. The county embraces a rectangular tract of land 38.6^{km} by 57.9^{km} in extent. Its western boundary is a meridian averaging about 37^{km} east of Lake Michigan at its widest part. Lacustrian influence upon the climate is probably felt throughout the county. Owing to the comparatively small extent of area, differences in climate between its different parts could hardly be pronounced enough to cause any marked difference in its vegetation. Also on account of the great distance apart of the stations for meteorological observations, if there were less differences between the climates of different portions of the county, such would not be brought out by any records which have been made. Therefore, a study of these meteorological data can hardly give any clue to the principles underlying plant distribution within the area.[2]

[1] A less technical account of the survey here presented was published in the Annual Report of the State Board of Geological Survey of Michigan, 1901, pp. 81–103, and it is through the courtesy of Dr. A. C. Lane, state geologist, under whose auspices the work was done, that the present account is published.

[2] Tables of the average temperature and precipitation by months for this region, compiled from the reports of the Michigan section of the U. S. climate and crop service, are to be found in the author's former publication, *loc. cit.*

The range of altitude over the whole county is less than 122^{m}, so that absolute altitude itself, with its concomitant variations in climatic conditions, is not a factor in the distribution of the flora. Differences in *relative* level, however, produce marked variations in the drainage, and hence in the water content of the soils.

2. GEOLOGY OF THE COUNTY.[3]— The bed rock of the area is almost entirely covered to a great depth by glacial drift, only a few small outcrops being found within its limits. The drift is so deep throughout the county that the underlying rock layers have apparently no influence upon the vegetation. But the drift itself presents some very interesting features.[4] The land consists, in general, of two great blocks of till upland lying on either side of a much lower gravel and sand plain of varying width, which extends in an irregular line from about the middle of the northern boundary southward through Cedar Springs, Rockford, Plainfield, Grand Rapids, Fisher, Carlisle, and Ross, and cutting the southern boundary about 4.8^{km} east of the southwest angle of the county. This plain traces the path of the outflowing water as the Michigan ice sheet retreated northward at the end of the last glacial epoch. An indentation or embayment in the southern ice margin during this retreat marked the junction of the two lobes of the glacier, the eastern lobe coming from the region of Saginaw Bay, the western from that of Lake Michigan. It was naturally into this embayment that much of the water was discharged during the melting process, and the line of sandy plains just traced marks, from Carlisle northward, the path of this gradually increasing notch in the edge of the ice. Southward of Carlisle the Green Lake sand and gravel plain (in Allegan and Barry counties) originated in the same way.

Three well-marked terminal moraines lie partly within the

[3] For a more detailed account of these features, see the author's previous publication on the same subject, already cited. A brief description of these features, by Dr. A. C. Lane, will be found in the introduction to MISS E. J. COLE'S *Grand Rapids Flora*, Grand Rapids, 1901.

[4] For aid in interpreting the glacial topography I am indebted to Mr. Frank Leverett, of the U. S. Geological Survey.

area. The southernmost, and hence earliest formed of these, follows roughly a line drawn through Ross, Carlisle, Middleville, and Hastings. The second passes through the middle of the county, the southern edge being now the northern boundary of the Grand River valley. The third moraine has its highest point northeast of Cedar Springs, and extends in an irregular and broken manner southeastward to the vicinity of Harvard, and northward and westward to Kent City and Casnovia. The second moraine is broken through by the valley of the Rouge River, and the third by the same valley and also by the sand plain north of Cedar Springs. These moraines are usually bordered by sand plains on the outwash side and by till plains on the side which was toward the ice sheet.

Most of the surface soil of the county is predominantly sandy. In classifying soils and designating them on the map, no attempt has been made to distinguish the different gradations between clay and sand. All soils which could not be termed either clay or sand have been bunched together as loam, in the broadest sense of that word, and denoted on the map by dots. More accurate records were made, but it was found that these minor differences of soil bore no apparent relation to the nature of the societies recorded, and it was thought best not to encumber the map with unnecessary details. Clay is denoted on the map by horizontal lines, sand by an absence of any marking. Sand and gravel plains of limited extent lie along almost every creek and about many of the lakes. No attempt has been made to map these smaller deposits.

3. METHODS.—Owing to the large proportion of cultivated land in the county, and the correspondingly small proportion which is in an approximately natural state, a study of the natural plant societies is necessarily a difficult one. From the more or less natural areas which still remain, an attempt has been made to reconstruct, as accurately as possible, the plant societies which occupied the region at the time of settlement. The effects of pasturing in wood lots have been allowed for so far as possible. Information has been gathered from local residents as to the nature of the forest which was removed in making certain fields

ready for the plow, and this information has been of great service in some instances.

The vegetation of the area falls naturally into two groups, that growing on what is commonly termed dry ground and that found in moist or swampy places. Each of these groups can be separated into several societies, which often merge gradually into one another, so that in some localities it appears that there is a mixture of several of them. But in general the division is sufficiently well marked. In the present paper attention will be confined to the upland group.[5]

THE PLANT SOCIETIES.

1. Classification.— The vegetation of the upland falls into five societies, which may be characterized as follows:

I. *Beech-maple society*, comprising as predominant and characteristic the following plants: beech, sugar maple, enchanter's nightshade (Circaea), wild licorice (*Galium lanceolatum*), wood nettle (Laportea), catnip (Nepeta), pokeweed (Phytolacca), richweed (Pilea), nightshade (*Solanum nigrum*), and red-berried elder.

II. *Maple-elm-agrimony society*, comprising sugar maple, American and rock elms, agrimony, spikenard (*Aralia racemosa*), honewort (Cryptotaenia), spice-bush (Lindera), moonseed (Menispermum), black snake-root (Sanicula), and wild black cherry.

III. *Oak-hickory society*, comprising white and red oak (*Quercus rubra coccinea*), shag-bark and pig-nut hickory, false Solomon's seal (*Smilacina racemosa*), northern bedstraw (*Galium boreale*), *Aster laevis*, and panicled cornel. This society is much the same as the following, but with the addition of the two hickories. It also has many plants in common with the previous society, and may be regarded as an intermediate type between II and IV, both of which are much more distinct. Owing to the difficulty of distinguishing sharply between *Quercus coccinea* and *Q. rubra*, these two forms have been brought together under the name *Q. rubra coccinea.*

[5] The study of the lowlands was not thorough. The reader will find a general statement of the lowland conditions in the previously published account, *loc. cit.*

IV. *Oak-hazel society*, comprising white and red oaks, *Aster laevis*, *A. macrophyllus*, New Jersey tea, hazel, spurge (Euphorbia), *Helianthus occidentalis*, *Solidago caesia*, and hoary pea (Tephrosia). The spurge found in this society is the broad-leaved form. In the following society this plant is just as common and characteristic as here, but there it has much narrower leaves. The individuals of the broad-leaved form appear stronger, greener, and more robust than the others.

V. *Oak-pine-sassafras society*, comprising white and red oaks, white pine, sassafras, plantain-leaved everlasting (Antennaria), wormwood (Artemisia), sand bur, spurge (narrow-leaved form), huckleberry (Gaylussacia), lupine, sweet fern, bracken, and *Solidago nemoralis*. This includes the dryest and most open form of "oak openings," together with the country which was once quite well covered with pine. They are put together here, because, aside from the now partially extinct white pine, the floras are practically the same.

A more extensive list of plants is given in the following table, which shows almost graphically the distribution of the enumerated plants throughout the five societies. The nomenclature is that of the sixth edition of Gray's *Manual*. The Roman numerals heading the five columns at the right of the names indicate the societies by number, the same method of indication being also adopted on the map. The letters opposite the plant names show in what societies the plant occurs, the relative abundance in that society being denoted by the letter itself. C denotes common: F, frequent; R, rare. An asterisk accompanying the letter expresses the fact that the plant is one of those to be regarded as specially characteristic of that society. Our *rare* has not the meaning given the word by the systematist; plants which he would consider rare are not sufficiently abundant to be considered at all in such a list as the present.

2. **Distribution.**—The distribution of the societies is shown on the map. From the darkest to the lightest of the five shades used a gradation is shown corresponding to that in the societies from I to V. The sixth and lightest shade denotes deeply-eroded channels occupied chiefly by lowland societies. In these

TABLE OF THE UPLAND PLANT SOCIETIES.

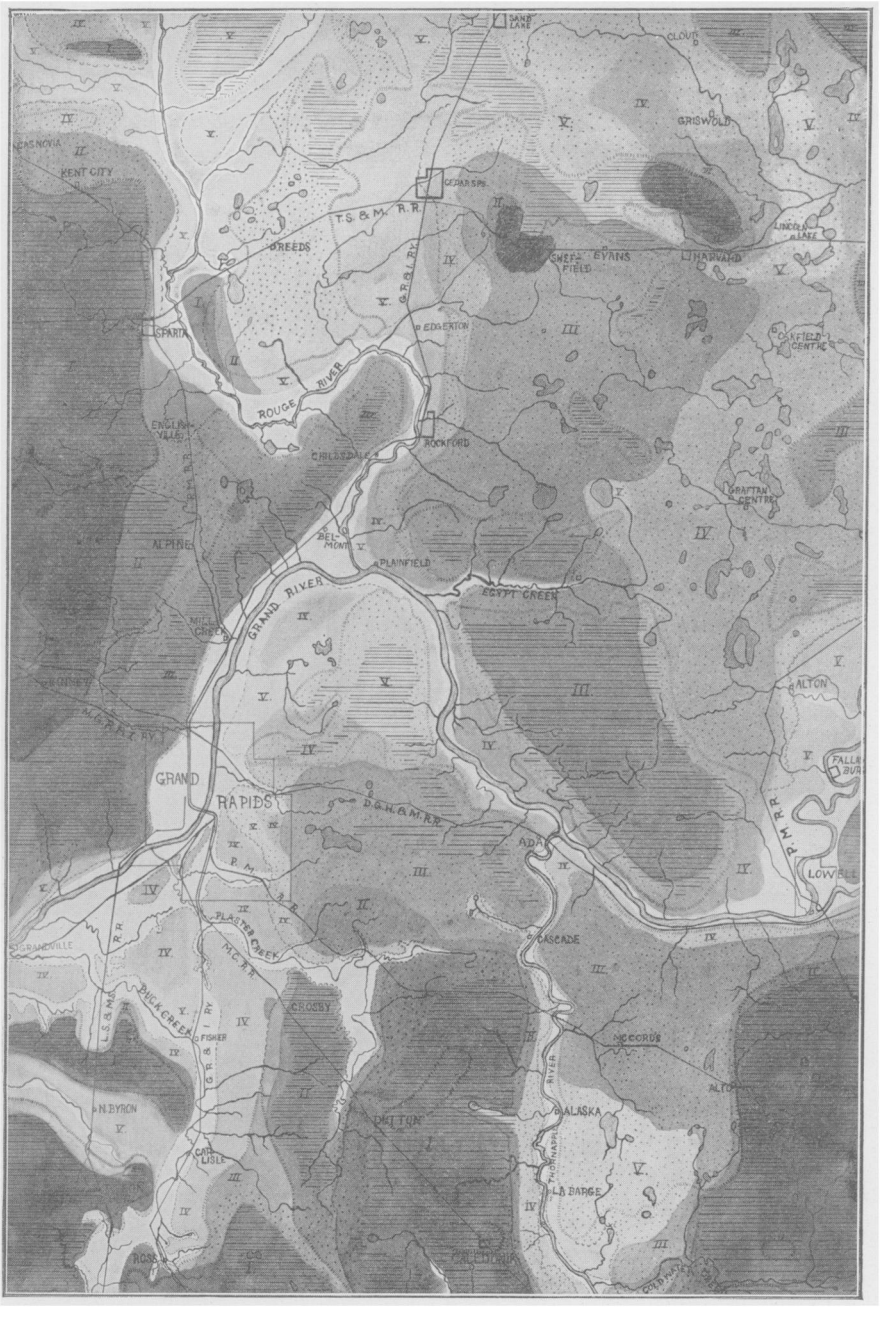
Species	Common name	I	II	III	IV	V
Acalypha virginica	Three-seeded mercury	F	F			
Acer rubrum	Red or swamp maple	R	F	R		
Acer saccharinum	Sugar or rock maple	C*	C	R		
Actaea alba	White baneberry	F*				
Adiantum pedatum	Maidenhair fern	...	F			
Agrimonia Eupatoria	Agrimony	...	C*	F		
Andropogon furcatus	Beard grass	...	...	...	...	C*
Antennaria plantaginifolia	Plantain-leaved everlasting	...	...	...	...	C*
Aralia racemosa	Spikenard	...	C*	F		
Artemisia caudata	Wormwood	...	...	...	...	C*
Aspidium acrostichoides	Christmas fern	F*				
Aster cordifolius		F	C	C		
Aster laevis		...	...	C	C*	
Aster macrophyllus		...	...	F	C*	
Boehmeria cylindrica	False nettle	C*	F	R		
Carpinus caroliniana	Blue or water beech	...	C*			
Carya alba	Shag-bark hickory	...	F	C*	R	
Carya porcina	Pig-nut hickory	...	F	C*	R	
Ceanothus americanus	New Jersey tea	...	...	R	C*	F
Cenchrus tribuloides	Sand bur	...	...	...	...	F*
Chimaphila umbellata	Prince's pine	...	...	R	R	F*
Circaea Lutetiana	Enchanter's nightshade	C*	R			
Cornus alternifolia	Alternate leaved cornel	...	C	C		
Cornus florida	Flowering dogwood	...	C	F		
Corylus americana	Hazel	...	...	F	C*	F
Cryptotaenia canadensis	Honewort	...	C*	F		
Cynoglossum virginicum	Hound's tongue	F*	R			
Diervilla trifida	Bush honeysuckle	...	...	...	F	C*
Dracocephalum parviflorum	Dragon head	F*				
Echinospermum virginicum	Beggars lice	C*	R			
Epigaea repens	Trailing arbutus	...	...	...	...	F*
Epiphegus virginiana	Beech drops	C*				
Euphorbia corollata	Spurge	...	...	F[6]	C[6]	C*[7]
Fagus ferruginea	American beech	C*	R			
Galium boreale	Northern bedstraw	...	F	C*		
Galium circaezans	Wild licorice	F*	R			
Galium lanceolatum	Wild licorice	C*	R			
Gaultheria procumbens	Wintergreen	...	...	...	F	C*
Gaylussacia resinosa	Black huckleberry	...	...	...	F	C*
Gerardia quercifolia	Smooth false foxglove	...	...	F	F	F
Geum album	Avens	...	C*	R		
Hedeoma pulegioides	American pennyroyal	F*				
Helianthus divaricatus	Sunflower	...	R	F	C	C*
Helianthus occidentalis	Sunflower	...	...	F	C*	F
Hepatica acutiloba	Liverleaf	C	C*	C		
Hepatica triloba	Liverleaf	...	...	C	C*	
Hieracium scabrum	Hawkweed	...	...	F	F	C*
Juglans cinerea	Butternut	...	F	R		
Juglans nigra	Black walnut	...	F	R		
Laportea canadensis	Wood nettle	C*	F			
Lechea minor	Pinweed	...	...	...	...	C*

[6] Broad-leaved form.

[7] Narrow-leaved form.

TABLE OF THE UPLAND PLANT SOCIETIES—*continued.*

Species	Common name	I	II	III	IV	V
Lespedeza polystachya	Bush clover				F.	C*
Lespedeza Stuvei intermedia	Bush clover					C*
Liatris cylindracea	Blazing star					C*
Liatris scariosa	Blazing star					C*
Lindera Benzoin	Spice bush		C*			
Lobelia inflata	Indian tobacco	C*	R			
Lupinus perennis	Wild lupine				R	C*
Medeola virginiana	Indian cucumber root	F*				
Melampyrum americanum	Cow wheat				F	F*
Menispermum canadense	Moonseed		C*	F		
Monarda fistulosa	Wild bergamot, horse mint, balm			F	F	C*
Monarda punctata	Horse mint					F*
Myrica asplenifolia	Sweet fern					C*
Nepeta Cataria	Catnip	C*				
Onoclea sensibilis	Sensitive fern		F*			
Ostrya virginica	Ironwood		C	C		
Phlox subulata	Moss pink					F*
Phryma Leptostachya	Lopseed		F*	R		
Physalis virginiana	Ground cherry					C*
Phytolacca decandra	Pokeweed	C*				
Pilea pumila	Richweed	C*				
Pinus Strobus	White pine				F	C*
Polygonatum giganteum	Solomon's seal		C	F		
Populus grandidentata	Large toothed aspen					C*
Prenanthes alba	Rattlesnake root		R	F	C*	
Prunus serotina	Wild black cherry		F*			
Prunus virginiana	Choke cherry			F	C*	
Pteris aquilina	Braken				F	C*
Pyrola elliptica	Shinleaf					F*
Quercus alba	White oak		R	F	C*	C*
Quercus ilicifolia	Black scrub oak					F*
Quercus rubra-coccinea	Red or black oak		R	F	C*	C*
Rhus copallina	Dwarf sumach				R	F*
Ribes Cynosbati	Gooseberry	C*	F			
Rudbeckia hirta	Browneyed Susan			R	R	C*
Sambucus racemosa	Red berried elder	C*	R			
Sanicula marylandica	Black snake-root		C*	F		
Sassafras officinale	Sassafras			R	R	C*
Smilacina racemosa	False Solomon's seal		C	C		
Smilax hispida	Greenbrier		F	R		
Solanum nigrum	Nightshade	C*				
Solidago bicolor concolor	Goldenrod			F	F	C*
Solidago caesia	Goldenrod			F	C	C
Solidago nemoralis	Goldenrod					C*
Solidago rugosa	Goldenrod		C*	F		
Tephrosia virginiana	Hoary pea			R	C*	C
Tilia americana	Basswood	C	C	F		
Ulmus americana	White or American elm	R	C*	F		
Ulmus racemosa	Rock elm	R	C*	F		
Vaccinium canadense	Blueberry			F	C	C
Vaccinium pennsylvanicum	Dwarf blueberry			F	C	C
Vicia caroliniana	Vetch		F	C*	C	
Vitis cordifolia	Frost grape		C	C		



UPLAND PLANT SOCIETIES
KENT CO., MICHIGAN.

MORAINE MARGIN
TILL PLAIN MARGIN
CHANNEL MARGIN
CLAY AREA
LOAM AREA

channels the areas occupied by the different societies are so limited that any satisfactory representation of them on the scale of the present map was deemed impossible. Therefore they are left unshaded. Also the lowland societies along the margins of smaller streams and lakes and in swamps among the hills are omitted entirely from the map. The reason for this is in part the same as the one given for the larger channels, and also in part this, that although some of the swamps are large enough to map well on the present scale, yet to trace their margins accurately would require more time than it would be worth, and to map them inaccurately would not be true to the instinct of the work.

Steep slopes where erosion is at present rapid, as along the margins of the many stream valleys and along old glacial channels, are occupied by societies III, IV, and V. The character of the soil seems to make no difference here, the drainage being quite complete and the accumulation of humus impossible. It has also been found impracticable to indicate these very narrow areas upon the map.

In the southern tier of townships, all the heavy clay soil, whether it be rolling moraine or level till plain, was originally occupied by the beech-maple society (I). In the lighter loamy soils are usually found the oak-hickory society (III), with transition zones between it and I held by the maple-elm-agrimony society (II). The very sandy loam bordering the deep narrow valley of the Thornapple River, and spreading eastward from Alaska and Labarge nearly to the Elmdale till plain, is occupied by the oak-hazel and the oak-pine-sassafras societies (IV and V). This loam is in many places as sandy as the soil of the Grand River sand plain; it might almost have been denoted as sand.

Within the "big bend" of the Grand River is an area of decidedly clayey country occupied by the oak-pine-sassafras society (V), although here the pine is not at all prominent. It appears as though this area were well on the way toward society IV at the time of clearing. But the marked presence of sassafras, wormwood, sand bur, *Solidago nemoralis*, and other forms of society V, makes it impossible to classify it elsewhere.

The Grand Rapids sand plain (reaching from Rockford, through Plainfield and Grand Rapids to Grandville and Ross) is generally covered with societies IV and V. The foundation soil is apparently the same throughout, being a gravelly sand, but the areas of society IV have undoubtedly more surface humus, thus giving the soil a darker color and a more loamy texture. The higher parts of the plain, and hence the portions which have been out of water longest, are generally the portions which show this condition. The lower portions where violent water action probably continued after the main stream receded, and where, owing to the slope, erosion is even now well marked, bear little surface humus and are characterized by society V. Here, at the time of clearing, the pine was usually present. Transition areas between IV and V were covered with "oak openings," however. Much of these channel areas is swampy and hence thrown out of the present discussion.

North of Grand River it is only in the western column of townships that the heavy clay is characteristically covered with society I. In other portions of the region the clay is mainly covered with society III, IV, or V. It will be noticed that clay which bears the oak-pine-sassafras society is common in the extreme north and becomes less common southward. Societies III and IV approach each other in character as we pass northward. The hickories become less frequent and the general aspect of III becomes more that of IV. It needs to be remarked here also that the stretch of society III, reaching from the Rouge River southward and lying west of Grand Rapids, is a curious mixture of II and IV. Judging from the trees alone, the southern part of it should be placed in society II, but the presence of New Jersey tea, *Solidago caesia*, etc., seems to place it in the oak-hazel group. Sassafras is present here to a remarkable extent, and in many places, especially to the north, white pine also. The northern part of this stretch contains much pine. Altogether, the area can better be classified under III than otherwise. In the general discussion to follow the possible reasons for the mixing will be considered.

In the bit of beech-maple society in the extreme north-

western part of the county is found the only marked instance of the presence of hemlock. This tree belongs typically with the hard wood group in northern Michigan.

In the northern part of the county white pine was almost universally present in the uplands at the time of settlement. This can be proven by stumps which are still in place or have been used in the construction of stump fences. There are pine stumps and a few trees still standing even in the beech-maple group upon areas north of an east and west line drawn through a point about midway between Cedar Springs and Rockford. South of this line the pine disappears in society I and becomes very rare in all but IV and V.

3. Generalizations on the upland flora.—Any sort of generalization upon the study of such a limited area as the present must necessarily be a hazardous undertaking. I venture to call attention to the following points, however, all of which must be looked upon as merely tentative suggestions:

a. *The soil factor.*—It appears that the general distribution of the upland societies is based primarily upon the nature of the superficial soil. This must be so, since the roots of the smaller plants never penetrate very far into the soil, and since, in the case of trees and shrubs seed germination and the growth of seedlings is conditioned by the surface layers. If seedlings cannot develop it is clear that there can be no mature plants.

It is very probable that the original till material covering Kent county was reasonably uniform in chemical constituents. That it was thoroughly mixed by the movement of the ice sheet is shown by the wealth of different minerals to be found in any small region. In spite of the marked washing, the most sandy soils contain a considerable amount of minerals other than silica.[8] The plant can make use of the soil constituents only after they are in aqueous solution. The great bulk of the soil is practically insoluble in water, and it makes no difference to the plant what may be the chemical nature of these undissolved substances. Thus it would seem much more to the point to make

[8] KEDZIE, R. C., Analysis of soil of jack-pine plains near Grayling, Michigan. Annual Report Mich. Board of Agriculture **27**: 211. 1888; also Bull. 99, 1893.

analyses of the soil water, for it is this which affects the plant directly. Such analyses were not made in connection with the present work, but it is hoped that they will be made at some future time, either for this region or some similar one. It is very probable, however, that soil waters from the surface soil in different parts of this area will be found to be very nearly uniform in the salts contained. This conclusion results from two considerations: first, the chemical nature of the soluble part of the surface soil itself is very nearly uniform throughout the county; second, the washed soils are usually comparatively shallow, and upward diffusion of dissolved substances probably takes place with comparative rapidity, especially when aided by the soil currents produced by changes of temperature, evaporation, etc. The only localities where it is at all probable that a paucity in soluble salts will be found to occur in the soil water are the deep sand plains. There is some rather questionable evidence from the vegetation that such is the case in these localities, but as yet no definite decision can be made in this regard.

In classifying soils according to their physical nature, the only question which has any direct bearing upon plant growth is that of the ability of the soil to retain water by capillarity, so-called. Primarily, this ability depends upon the size of the soil particles. Thus sand will retain less water than will loam, and loam will retain less than clay. Sandy soil may be made to retain more water in two different ways, either by the addition of clay or by the addition of humus. The physical effect of humus is very well marked. Of course the humus also adds some nitric acid and certain organic materials which are of benefit to the plant, and it also increases the amount of soluble salts at or near the surface; for humus is formed mainly from leaves, and in these organs the mineral part of the plant body is concentrated. This is perhaps an important fact in the growth of hard wood upon deep sand which is well covered with humus. Where drainage is complete and rapid, as in sand, and oxidation is also rapid, humus does not readily accumulate; but where it does accumulate as a surface layer, the ability of the soil to retain water approaches that of clay.

From the present study it appears that the most important soil factor in the distribution of the flora of Kent county is this one of the relative ability of the superficial layers to retain water. In other words, *the controlling soil condition is one of drainage.*

Throughout the southern half of the county, soils which retain much water are covered with society I, II, or III. The only exception to this is the small clay area within the bend of Grand River. The soil of this area is apparently as good as that farther south, but it is very dry in dry weather, and there is no marked humus covering. Perhaps the proximity to the well drained valley on either hand has an influence through underground drainage, but this was not looked into, and the question must be left for the present unanswered.

Within the sand plain area of the southern half of the county there are several small stretches of societies I and II. Owing to the fact that at one time a much larger stream than the present one flowed through the valley of the Thornapple River, that valley has a well marked terrace between the country level and the present flood plain. This old flood plain is sandy and corresponds in manner of formation to the Grand Rapids sand plain. But in very many places this terrace is covered with societies I or II. Some of the finest "sugar bushes" to be seen in the county are here. The sandy soil is thickly covered with a layer of humus. These strips of hardwood are so narrow that they could not well be shown upon the map. The same condition holds on the rather high part of the plain lying west of Crosby. This is indicated upon the map. Also at the base of the escarpment forming the margin of the deeper glacial channel in the Grand Rapids sand plain, there are several instances of societies I and II upon humus-covered sand. Notably is this true near the southwest corner of Grand Rapids and on the margin of the Buck Creek valley near the Lake Shore and Michigan Southern railroad. In this connection it is interesting to note that beech trees are found quite commonly upon the humus-covered established dunes along the east shore of Lake Michigan.[9]

[9] Dr. Cowles tells me that he has seen these beech covered dunes as far north as Frankfort, and Mr. Whitford has observed them on Manitou Island.

In the northern half of the county, west of the Rouge River, we find the heavier soils still retaining societies I, II, and III. East of the valley of this river we find the country is much cut up. The clay areas are small and rather well drained. They may be occupied by any society from I to V. That they can support society I is well shown by its occurrence in several places. Its general absence from this region is perhaps due to another cause, to be mentioned later.

East of Sparta and northeast of Cedar Springs are perfectly typical examples of society I growing upon light soil, the former without trace of pine. In the western part of the Sheffield area I was told by a resident that the clay was at least twenty feet below the surface. But in these areas the soil is deeply covered with humus. What the conditions are which cause the accumulation of humus in one place and not in another apparently similar place, I was unable to make out. This accumulation most often occurs in rather low regions, where the sand would normally remain moist longer than elsewhere. The maple-elm-agrimony society grows to perfection on heavy soil with little or no true humus. It is also found on lighter soil which has a humus covering.

In the southern half of the county it seems fairly clear, then, that societies I and II will grow on rather deep sand if that be covered wiih humus, and that when society V is found on clay it is well drained and usually with little or no humus. Throughout the county there is an obvious difference in humus content between the areas occupied by societies IV and V, the sand of the former being mixed with vegetable débris. The intermediate society III is found on the loamy soils and on the dryer and better drained clay areas.

b. *The historic factor.*—Besides the factor of relative water content in the soils there is another which may be active in this region, namely, what may be termed the historic factor. As the ice sheet retreated slowly northward at the end of the last glacial period, the portions of Kent county first uncovered were of course in the southern part. And the first parts of the sand plains to be uncovered lay also at the south, although these areas

were probably under water long after the ice itself had disappeared. It is probable that the pine-heath [10] group, which today reaches farthest north, reached well toward the glacier front during the ice age. And at the end of that age, the ice in its retreat was probably followed northward by vegetation, the pine-heath society leading the way. Near the ice margin the soils were probably raw, absolutely without humus, subject to great drought in summer and to extreme cold in winter. These are just the conditions in which the pine-heath group is found today in northern Michigan. It is probable that at one time they occupied all of Kent county, but the climate became warmer and more equable with the farther retreat of the ice, and the growth of the hardy pines, etc., produced a little humus. Their roots fixed the soil so that erosion was less rapid and perhaps the sassafras and the white and red oaks and the whole of our society V gradually crept in, occupying the better part of the ground along with the pines and heaths. Then, as the soil improved, the oaks became more and more numerous, and the pine seedlings could not develop on account of the shade. The pines thus became fewer in the south and the oaks at last predominant. This would be the stage of society IV. But the process of working over the soil continued, though perhaps the ice-sheet had shrunken by this time nearly to its present size, and humus continued to accumulate in favored places; the hickories, maples, and beeches of Ohio and Indiana spread continually northward over every suitable stretch of soil, as fast as it was made fit for them. When the maples and beeches reached maturity in the richest parts of the oak and hickory forest, the oaks and hickories probably ceased to mature. Seedlings of these trees fail to develop well under maples and beeches, possibly on account of the dense shade. Thus the stage of society I might be reached.

In such a northward advance, the plant societies would not progress in uniform lines. On the contrary, there would be many mixed areas, and the advance would often be almost

[10] This group comprises, besides several pines, two species of juniper, bearberry, hairbell, bracken, and several of the other forms found in our society V. Cf. WHITFORD, H. N. The genetic development of the forests of northern Michigan; a study in physiographic ecology. BOT. GAZ. 31: 289–325. 1901.

imperceptible. Here and there in a sterile, perhaps in a well drained, portion, would be left a detachment of the advance guard, like the patches of societies V and IV in the southern townships of the county. And these would be surrounded and left as relics by the later comers as they advanced, occupying all soils in which they could come to maturity, and preventing the development of new generations of the forms previously in possession. With these thoughts in mind, a glance at the map will suggest much more than was suggested before.

The beech and maple societies (considered by Cowles and Whitford[11] to be the climax society for temperate North America) extend northward along the lines of soil richest in water content, and reach farthest north in the western part of the county. This latter fact may be due to the lake influence. Chamberlin states[12] that in Wisconsin the beech is limited to regions near the lake. He believes its distribution to be determined by lacustrian climate. This is very doubtful, however. Also the other societies—II, III, and IV—are each a little in advance of the previous one, and each is apparently advancing into the area occupied by the next hardier one. In the extreme north we find almost the entire area occupied by societies IV and V.

According to this line of thought, the reason for the predominance of the pine groups in the northern part of the county is that sufficient time has not yet elapsed since the glacial period for these areas to be reached by the societies found predominant farther south. Along a wavy east and west line passing through Rockford lies the "zone of tension" between societies I, II, and III on the one hand, and IV and V on the other. This line bends far northward at the west, following the western edge of the Rouge valley as far as Kent City and Casnovia. It also bends northward to Sheffield and Harvard on the other side of the Rouge valley. It may be that the climate, somewhat colder as we pass northward, has acted as a retarding factor,

[11] WHITFORD, H. N., *loc. cit.*, p. 302.

[12] CHAMBERLIN, T. C., Native vegetation of Wisconsin. Geol. of E. Wisconsin 2: 176. 1873–1877.

assisted by the fact that a good portion of these northern townships have a light surface soil, which seems unsuited for the hard wood societies in the absence of humus. That the climatic factor is not the main one in this is shown by the existence of vast reaches of typical maple and beech forest in the northern part of the peninsula.

The strongest point in favor of the idea just expressed is found in the fact that at the time of settlement practically all of societies I and II in the northern part of the county were well mixed with pine. In some places the pine stumps are so numerous as to raise the question whether the hardwood is not an entirely recent development. It is probable, however, that scattered maples and beeches were mingled with the pine, and that on the removal of the latter their seedlings simply took possession of the ground and shut out the pine seedlings.[13] Also in societies II and III, west of Rockford and as far south as Mill Creek, the pine is still pronounced, and in many small spots society IV, or even V, still retains its hold. As has been noted before, this is a mixed group and is hard to classify. There are no traces of pine in the hard wood forests to the southward. It may well be, however, that a further extension of this study will show that this hypothesis of the historic factor is utterly untenable.

Another line of evidence seeming to throw some light upon the historical development of this flora is that obtained from a comparison of the several sand plains of the region. There is a well marked sand plain just south of the boundary of Kent county, which I have termed the Green Lake sand plain. The soil here is like that of the higher part of the Grand Rapids plain, very sandy, but with a good admixture and coating of humus so that at the surface it appears loamy. The vegetation is made up of all five of our societies. In general the type is that of society III, but there are many spots, especially on the

[13] Beal has shown that oaks, maples, etc., can reach a considerable age in dense forests without any marked growth. An oak may thus be twenty-five years old and yet have a height of only a few inches. If the shade-producing plants are removed these dwarfed trees will set up a renewed growth. For figures of such dwarfed trees see BEAL, W. J., Observations on the succession of plants in northern Michigan. Annual Report Mich. State Board of Agriculture **27**: 74–78. 1888.

margins of the numerous ponds and lakes where societies IV and V hold the ground. In slight depressions along the margin of the plain the humus is deep and society I is common. There are also many rather large areas of societies I and III well out in the plain. Usually these are in slight depressions, not low enough to be swampy, but well covered with humus. We may say, then, that in the most southern of the three sand plains which have been studied, and therefore the one which has been out of water and fit for vegetation the longest, the predominant society is III; but I and II are not uncommon; while IV and V occupy a relatively small portion of the area.

In the Grand Rapids sand plain, society IV is predominant, with a good part occupied by V and comparatively very little by I, II, and III. And in the plain which extends from Rockford northward, the only upland society found is V. Of course the last plain has been out of the water a much shorter time than the other two. In fact, a great part of it is at present swamp and is occupied by lowland societies.

In these three plains, perhaps, are seen successive stages of vegetation occupying successive stages in the formation and accumulation of humus. Of course the extensive destruction of the natural vegetation which has taken place since settlement of this region began will make it impossible for the natural course of events to continue here, even if the above hypothesis be the correct one. Clearing and burning have often reduced the soil from a condition suited to society II or III to one only fit for society V. This is probably also true on the moraines in the northern part of the county. It will probably be impossible ever to trace the history much farther than it had gone at the time of settlement.

CONCLUSIONS.

The present observations appear to justify the retention, as a broad general hypothesis, of the physiographic idea advanced by Cowles, namely, that physiography determines vegetation. But this hypothesis does not come close enough to the ultimate factor upon which depends the distribution of the plant

societies. The ultimate cause of all this varied vegetation must be something more particular, something which will affect the individual plant. For such a region as this, this *something* must exist in the nature of the soil; climatic factors cannot explain differences in such a small area; and the historical factor is broad and general, like the physiographic one, and hence is not ultimate. That local differences in vegetation are due to soil factors has been practically proved before this, and the proof is strengthened by the present study. The physiographic hypothesis explains how it is that various soils may be physically and chemically different. But, after this is explained, the question with which we have to deal lies still untouched: *What is it in the nature of the soil which determines the distribution of our plant societies?*

Now, by "nature of the soil" two things may be denoted, and only two, *i. e.*, the *physical* nature and the *chemical* nature. But neither of these can influence the plant *per se*. Either one of the features may be effective, however, through soil water. Water is the only feature of the soil which comes in direct connection with the vitality of the plant. The chemical nature of the soil may be directly effective through the nature of the dissolved substances which enter the plant, or indirectly, through osmotic pressure. Its physical nature may be effective through the retention or non-retention in the soil of the water itself.

So far we may go *a priori;* beyond this, tests must be made. The nature of the soil water from various soils in various positions must be carefully determined. From these determinations will be shown how much truth or falsity there is in the explanation here offered, that the nature of the soil water is not usually a decisive factor for such a region as this.

Also, by careful tests the ability of various soils to retain water must be determined, and these determinations recorded with the vegetation found growing where the tests were made. Thus, and thus only, can the hypothesis here offered be tested, *i. e.*, the hypothesis that *the decisive factor in plant distribution over a small glaciated area is, in most cases, the moisture-retaining power*

of the soil.[14] Mere field observations can neither destroy this hypothesis nor establish it.

On the other hand, the present series of observations seems to show that the historic factor may be a very important one in the distribution of the plant societies of Kent county, and the test of the hypothesis offered in this connection is to be obtained through observation and comparison, and through them alone.

It is hoped that in the future studies may be made of other areas lying north and south of this one, and the results carefully mapped and published. Emphasis is here laid on the map, for by it alone can a satisfactory comparison be instituted. Photographs are apt to be too superficial to be of any accurate use, though they would undoubtedly be valuable in connection with the map.

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[14] Similar conclusions to the one here expressed have been published by Mr. Bruncken. BRUNCKEN, E., Studies in plant distribution. 1. On the succession of forest types in the vicinity of Milwaukee. Bull. Wis. Nat. Hist. Society **2**: 17–28 1902.